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Urban Artificial Intelligence: From Automation to Autonomy in the Smart City

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Abstract— *The primary aim of this paper was to examine how urban artificial intelligence operates regarding automation and autonomy in smart cities. Technological innovation is transforming the materiality and dynamics of smart-city programs continuously. Lately, advancements in artificial intelligence (AI) in the form of self-driving vehicles, robotics, and city brains have pushed the so-called smart city to evolve into an autonomous urban monster that is still mostly unknown to the public [1]. Smart cities are becoming more autonomous, with artificially intelligent entities taking over the administration of urban services and municipal government from humans and administering the city in a self-sufficient way. This study investigates, both theoretically and practically, how the growth of artificial intelligence overlaps with the development of cities. This paper develops a theoretical framework for understanding artificial intelligence (AI) in urban contexts. Specifically, it advances the notion of urban artificial intelligence by documenting the most prominent manifestations of AI in urban environments.*

Keywords: *Artificial intelligence, smart city, urban artificial intelligence, automation, autonomy*

I. INTRODUCTION

With artificial intelligence (AI), computers will have cognitive capacities that are like those of humans, and this will have profound effects on people's everyday lives, economic patterns, and the way governments run their affairs [2]. In the urban environment, there are high expectations for artificial intelligence. Even while there are many arguments regarding the advantages and disadvantages of artificial intelligence in general, there has been less discussion concerning the particular effect of AI on cohesiveness within and across metropolitan areas [2]. It examines the current level of knowledge on the role of artificial intelligence (AI) in urban development, including its possible benefits and threats, as well as the implications for socio-economic and topographical cohesion that may be predicted [3]. Several cities are now undergoing smart city development. An overwhelming number of smart-city programs are now being implemented over a wide range of geographical locales, based on a complex tapestry of urban ideas, as shown by a handful of studies. Information and communication technology (ICT) is a unifying denominator throughout this broad pool of ostensibly smart cities [3]. Many different technologies go into a smart city, but they all work together to create a significant amount of data on the metabolism of a city, such as how much energy is used and how people move about. Smart urbanism advocates argue that big data may be used to enter and wipe out cities' figurative "heart of darkness" to get a scientific understanding of how they work and make them more environmentally friendly [3,4]. Although smart cities are supposed to have a scientific aim, their commercial and political ambitions have often been concealed under the guise of science.

Artificial intelligence-based technologies are still in their infancy, with AI systems performing tightly specified tasks that are driven by data analysis at this point. Recent advancements include the creation of self-improving machine-learning algorithms that don't need precise instructions from their designers [5]. For an urban environment, AI may integrate and synergistically use vast amounts of data created by everyday city life with other communications technology (Big Data, Internet of Things, Cloud, telecommunications architecture). To reap the full benefits of interconnectivity, a fully integrated system, in which data from many sources is merged to provide relevant information, must first be developed and implemented [5]. As a result, artificial intelligence helps to the complete realization of the smart-city paradigm. There is no one definition for what constitutes a smart city, but it is usually understood to refer to a collection of activities aimed at using digital technology, such as artificial intelligence, to increase well-being and the overall quality of life. Not all smart cities are necessarily powered by artificial intelligence, but the more sophisticated ones almost always are [6]. Nonetheless, the notion of a smart city encompasses a larger range of activities than the concept of a digitalized city. It necessitates the

establishment of systems to "govern" technology innovations, such as those involving community engagement [6]. The use of artificial intelligence (AI) in a city environment may give a variety of solutions in a variety of sectors, ranging from enhanced urban administration and decision-making assistance to the release of new or better services for people and the establishment of new economic possibilities [6,7]. As a result, artificial intelligence (AI) in smart cities has the potential to have a significant influence across a wide range of application areas. These domains include (but are not limited to): local government; health; safety; mobility; and energy. Many of these areas are crucial for city administration as well as urban growth. Among other things, artificial intelligence is projected to allow efficiency improvements, greater governance, democratic involvement, and increased environmental protection.

II. PROBLEM STATEMENT

The main problem that this paper will address is to review how artificial intelligence can be utilized in smart cities. In addition to digital innovators and ecosystems, data and infrastructure are found in abundance in cities, which makes them ideal locations for digital transformation. Meanwhile, digital technology may be utilized to enhance urban places while also safeguarding the environment and guaranteeing a good quality of life for both residents and visitors. This research paper discusses the prospects for urban sustainability that artificial intelligence (AI) in particular may give, as well as the role that AI can contribute in an integrative approach to executing the vision 2030. One of the most important and powerful drivers of change of the twenty-first century is the ongoing acceleration of urbanization [7,8]. The sustainability targets featured in the 2030 Agenda will be determined by what we accomplish in cities. In urban centers about two-thirds of all sub-objectives may be attained. To accomplish these goals, management at all levels will need to be completely incorporated with a wide range of diverse stakeholder organizations [8].

III. LITERATURE REVIEW

A. What is Artificial Intelligence?

There is no universally agreed meaning of the word "artificial intelligence" at present. Generally, it refers to scientific endeavors by scientists to teach robots how to learn autonomously or to automate cognitive activities such as pattern identification, planning, language, and text or voice recognition (to name a few examples). As a result, artificial intelligence (AI) is not a standalone system, but rather a collection of technological procedures, the majority of which make use of versions of machine learning (ML) [8]. The knowledge and learning algorithms (code) are merged into a software system, from which conclusions (probability-based conclusions) are derived and backed by strong equipment in these technological procedures. This fundamental approach inside machine learning processes – i.e., utilizing training data to instruct the machine, which subsequently draws inferences when it encounters fresh data – serves as the foundation for the vast majority of artificial intelligence systems. Unlike conventional software, which requires all inputs and outputs to be set in advance, AI systems are capable of self-learning and, as a result, are continually improving at what they do. The majority of contemporary artificial intelligence systems are programmed to do a certain purpose (this is referred to as 'narrow AI') [9]. They aid people by making it simpler for them to do their duties and, to a certain degree, by automating these chores at the same time. Despite recent advances, researchers are still decades away from developing the "general AI" that has been the subject of generations of science-fiction movies.

B. Having access to large amounts of computational power

Training artificial intelligence algorithms necessitates the use of large amounts of computing power, which may be obtained either locally or through the cloud. Only a very tiny proportion of international partners have their supercomputers (with India, South Africa, and Brazil serving as obvious exceptions), and the number of services that can be performed in parallel on these machines is restricted. As a result, AI entrepreneurs in the global south create their AI solutions mostly via the use of cloud computing and/or pre-trained algorithms, rather than from scratch. The global cloud computing business is controlled by a small number of companies centered in the United States and China [9, 10]. Algorithms may be trained in other countries by developers and technological partners. All of these choices come at a high financial expense, and they may be subject to restrictions under relevant data privacy law, particularly if the training entails the transmission of personal data to a foreign nation [10].

C. Software, algorithms, and developers

A wide variety of open-source software frameworks and algorithm repositories are available for creating artificial intelligence (AI) systems [10,11]. However, before it can be utilized, the software that is made accessible in these settings must first be customized for its intended function by artificial intelligence professionals. City governments will need to create new capabilities and recruit machine learning professionals (AI expertise) to their areas as a result of this development. These experts are often mathematics or computer science graduates who have a strong command of many programming languages as well as a grasp of hardware and software architectures. They collaborate with an interdisciplinary team of data scientists and software programmers to construct artificial intelligence systems. As a general rule, low- and middle-income nations are notably short of professionals in the first group, which is particularly true in the former [11]. In addition to technological needs, artificial intelligence necessitates the establishment of a legislative framework that addresses data management and digital business models. Users and regulators alike must also learn the digital skills necessary to recognize, construct, and utilize beneficial apps to be successful.

D. Understanding artificial intelligence in the context of urban life

Practitioners have long placed a high value on data when it comes to planning, building, and operating built environment systems. This physical system construction involves a deep understanding of several technical, geographic, and design concepts, all based on mathematics. In the ancient era, like today, quantitative data and mathematical concepts were required to properly execute large-scale undertakings. The digital revolution has only increased the necessity for data-driven building management to better implement the urban landscape. Nowadays, almost every human action leaves a digital trail: commercial transactions, phone conversations, and texts, GPS navigation. With a smartphone, merely traveling from one community to another produces a data trail as you leap from one cell tower to the next, creating a data trail in the process. Meanwhile, the machinery used to create our facilities and infrastructure has been digitalized, with several units capable of wireless data export [12]. Aside from that, the computer industry is always innovating, producing ever-increasing processing power, storage capacity, and analytic software. We're just inundated with information and computing power these days. The issue is how to make the most of data's potential worth. Increasingly low-cost environmental sensors and network devices are being manufactured, allowing more people to benefit from the Internet of Things (also known as IoT). The ability to employ dependable mobile telephony and cloud computing is also enabling IoT to become a reality [12]. With IoT, sensors installed in diverse built-environment systems and equipment may communicate with one another, boosting data volume and speed, and allowing new chances to link physical activities.

In the process of evolving, a new kind of data-driven approach to urban administration has been developed, which many cities refer to as smart city initiatives. There is no universally accepted definition of a smart city initiative, and apart from online lists, there is no means to determine whether a whole municipal or urban region is "smart." However, the use of networked sensors, system integration, and analytical platforms to improve the performance and operation of substantial and sustained is a common feature [12]. Artificial intelligence comes into consideration in this situation. When used in combination with machine learning, artificial intelligence is well-suited to serve as the analytical underpinning for smart city initiatives. Massive amounts of data are generated by built environment systems, and machine learning can analyze this data to provide automatic, real-time responses when appropriate, as well as give digestible insights for people to take into consideration. In addition, since data volumes will continue to expand at an exponential rate, local governments, and their partners will be able to apply artificial intelligence to exploit the potential presented by the data avalanche [13].

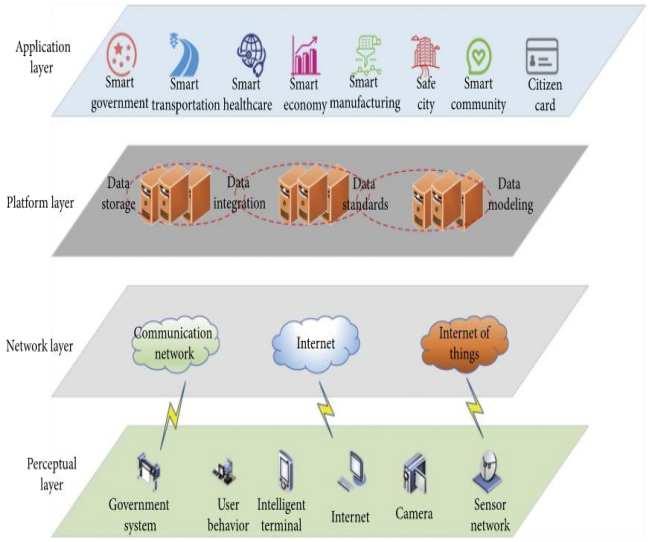

Figure 1: The fundamental design of a smart city

E. AI in urban development

Instead of focusing on gathering data and learning about a city's complexity and dynamics, artificial intelligence (AI) enables cities to use that expertise and insights to make better decisions. The term "urban AI" refers to "artifacts functioning in cities that are likely to obtain and forming a sense of information about the underlying urban setting, and ultimately acting rationally in complicated urban circumstances where some information may be absent or incomplete." [13]. More than a third of smart city applications will be enabled by AI by 2025, including urban transportation systems, which will have a substantial impact on the resiliency, efficiency, welfare programs, and vibrancy of urban life. Applications of Artificial intelligence in smart cities may include but are not limited to: enhancing water and energy infrastructure, enhancing city services, as well as fostering resourceful and sustainable communities. Local governments, people, and other smart city players, on the other hand, confront several obstacles in putting these technologies into action.

F. AI as a tool for creating new and improved services

Smart cities make use of cutting-edge technology to improve and modernize existing infrastructure and services. Using artificial intelligence (AI) to enhance smart services such as lighting systems and smart waste management is the focus of this section. In the EU, cities have up to 90 million streetlights, which use 20 to 50 percent of the city's energy budget. Over 75% of the streetlights in the city are over 25 years old and in need of replacement [14]. Many cities provide other forms of illumination in public areas like parks and beaches beside street lights. Smart city lighting is often cited as the way to get a city started on the path to smart city development. Combining more energy-efficient and enhanced public illumination with monitoring and controlling, lampposts are an excellent item to outfit with the Internet of Things sensors that can collect, transmit, and locally analyze data

on traffic patterns, environmental elements including such pollution levels, temperatures, wind velocity, and humidity, as well as audio data for gunshots tracking, urban noise and other applications. This is why the Humble Lamppost EC program helps communities install 10 million smart streetlights by 2025[15]. Major cities including Barcelona, Rotterdam, Munich, and Copenhagen have innovative uses. Smart lighting technology is used in Barcelona to keep an eye on how many people are using the city's beaches and public spaces so that crowds may be better managed. Garbage management is another example of a smart city innovation in public services since it involves both wastes gathering and management. By adding sensors to trash containers that monitor the filling rate and anomalies in its functioning, efficiency improvements may be realized through smart collection routing according to the filling rate, but also reduced irritation for people caused by full or faulty containers. Artificial intelligence (AI) may be used to make predictions about how, when, and where the garbage will be thrown away, giving city planners new tools to encourage the efficient waste generation and disposal among residents. Artificial intelligence (AI) may also be used to improve the sustainable processing of municipal solid waste (MSW) [15]. Computer vision may be used to separate trash flows for re- or upcycling in cities where garbage separation isn't yet commonly practiced. Urban data platforms (UDPs) are becoming more widespread in urban areas as a response to the digital economy, which has given rise to major digital platforms like Uber, Airbnb, and Google, among others, and as a recognition that municipal resolutions can only be achieved via the cooperation of reliable and efficient datasets and infrastructures. These UDPs bring together data gathered around the city. There are 32 operating UDPs in Europe, according to 2019 research, with the other cities either considering establishing a UDP or planning and executing one [16].

G. The advantages of smart city artificial intelligence

Improving a city's connection is a critical enabler for making it smarter. Their data accessibility and network bandwidth, especially their Internet of Things (IoT), significantly influence what the city can provide stakeholders. Due to what is known as the network effect, artificial intelligence refers to the ability of code to learn and remember human preferences, allowing it to begin making choices for us and taking over complicated operations and procedures on our behalf as platforms grow in size. Even in its most basic form, it symbolizes the ability to handle large amounts of data at high speeds while maintaining accuracy. It makes perfect sense to use machine learning models to make operational choices in smart cities [16]. When it comes to smart cities and AI, low-cost bespoke manufacturing of any product precisely when and where it's required might be an enormous value (generally referred to as Industry 4.0). Manufacturing automation decreases labor costs, rendering local production more affordable and countering the tendency to 'offshore' it. As Industry 4.0 — a mix of robots and intelligent, teachable software – becomes more extensively deployed, this trend is projected to continue [16]. Manufacturing will undergo a radical transformation as the future of production relies more on flexibility than on size. Robotics and machine learning have already been merged in the retail and aerospace sectors to prepare shipments for Amazon and simplify the fabrication of 3D-printed jet engine components. This is expected to improve economic development by improving productivity.

In healthcare, AI is poised to have a significant impact. By pre-screening patients and only needing the involvement of a skilled physician in cases where an unambiguous negative cannot be established, machine learning has the potential to boost diagnostics. Anything that minimizes the time it takes to find a new medicine would save money on research and development, resulting in reduced drug prices. This will make pharmaceutical corporations more interested in developing treatments for diseases that are exclusively found in developing nations. These advantages should also help to bring customized therapy closer to its goal [17].

IV. FUTURE IN THE U.S

The future of artificial intelligence in developing smart cities will continue to advance for many cities in the United States. Many cities around the nation are already seeing the fruits of such innovation. Perhaps predictably, New York City consistently ranks high on lists of smart cities in US and worldwide polls, and it ranks first on the list. The Smart City New York worldwide conference is held in New York City every year. Every day, the city of New York requires one billion gallons of water. As a result, the city has installed an Automated Meter Reading system to monitor water use and provide city residents with an accurate picture of their water demand [17]. New York City has hundreds of additional smart sensors in addition to water sensors to keep tabs on anything from garbage bin waste levels to the quality of the air. On city streets, hundreds of touchscreen kiosks have been built where citizens can charge their phones and get information about the city. Cities' future depends on combining new technology with existing infrastructure to address real-world problems like environmental sustainability and economic opportunity. Smart cities have the advantage of not needing significant initial investment. It's true that installing auto-dim streetlights, adding smart water meters, and implementing traffic management technologies that decrease infrastructure and ongoing maintenance are all low-cost solutions to high-cost issues that pay for themselves over time in reduced expenses [17].

V. ECONOMIC BENEFITS IN THE UNITED STATES

Connecting all of the devices in a city makes it more efficient, and that efficiency has a direct impact on the economics of most cities in the United States. The use of digital infrastructure in metropolitan areas has been shown to have still another benefit: economic growth. It used to be

that this particular feature was often misinterpreted, and as a consequence, it was seldom acknowledged. However, according to the latest analysis, the Smart City paradigm has the potential to boost economic growth in cities by more than 5% and generate an extra $20tn in global economic benefits by 2026. Aside from delivering intelligent solutions and reducing expenses, smart city technologies can provide new possibilities for generating cash via clever initiatives [17,18]. Using Intelligent systems efficiently and developing a road toll system that reduces parking fraud may be as easy as leveraging the city council's control of data and urban infrastructure to create new methods of earning public money. Data generated by smart sensors on citizens' wants and behaviors is huge. The government is restricted in what it can share with companies due to ethical, legal, and political considerations, but the government may monetize the data to some extent, enabling it to produce value for its citizens. Paywalls are being used by cities like New York to charge private sector organizations for access to their data. Additional cash may be obtained by making the most of sponsorship possibilities.

VI. CONCLUSION

This research reviewed how artificial intelligence is advancing the development and improvement of services of cities. According to the findings of this study, artificial intelligence has the potential to accelerate urban development. Researchers believe that since smart urbanism's face changes so rapidly, it's difficult to distinguish between what's being said and what's occurring. The dynamics of smart urbanism alter when a new kind of smart urban technology is launched into the market since smart city initiatives are fueled by quick technical innovation processes. For a long time, futurists have predicted smart cities, where inhabitants and tourists would coexist peacefully. These contemporary urban landscapes buzz with sophisticated multi-modal transportation systems, self-sustaining energy grids, clean and secure communities, integrated services, and significant amenities that have been fine-tuned and smoothly run. Cities and towns continue to confront significant problems, such as maintaining infrastructure and dealing with population expansion and migration, as well as sustainability concerns. It follows from this assumption that a smart technology's revolutionary and disruptive nature determines how much of a city's character it will alter. Artificial intelligence has created this conflict (AI). Today's AI innovations, such as self-driving vehicles, robotics, and autonomous platforms for managing urban infrastructure, are propelling the smart city to become a creature of the city that is yet mostly unknown to most people. A comprehensive approach aids in finding solutions for all facets of urban life, from schools to companies to transportation to energy. If we work together, we can bring new ideas and technology to bear in practical ways that benefit people and build a more promising future.

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